

FINAL REPORT

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THEORETICAL EVALUATION OF THE RADIATION HAZARDS FROM COSMIC RAYS
WITHIN SPACE VEHICLES

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DEPARTMENT OF PHYSICS AND ASTRONOMY

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I. This investigation has proceeded as specified in the proposal dated 1 January 1992. Results have been presented orally at many professional meetings, have been published in refereed journals, and as NASA technical papers. In large measure our progress has resulted from collaboration with NASA personnel, principally F. A. Cucinotta, J. W. Wilson, and others.

2. We may summarize our efforts as follows:

a. Improvement of our calculations of the radial dose distribution from delta rays ejected in the passage of heavy ions through matter through the application of new data to a previous calculation by Kobetich and Katz (1968). Supplementing this calculation, we have found the radial distribution of electron energy spectra and the radial distribution of microdosimetric quantities (Cucinotta et al, 1996, 1997)

b. Extension of the Katz model of cellular survival to bacteria, to lethal mutations in *C. Elegans* in vivo, to mutation induction in vitro, to thindown in radiobiology (observed experimentally at GSI, Darmstadt, and there called "Darmstadt hooks", predicted by Katz theory years before GSI was constructed).

c. Coupling the Katz theory of RBE to the NASA theory of the diffusion of heavy ion beams in matter (including target and projectile fragmentation) to yield predictions of radiobiological effects for monoenergetic heavy ion beams as well as range modulated beams used for cancer therapy. Here we have directed attention to the role of "ion-kill" (the effects produced by heavy ions passing through the nucleus of a cell), responsible for increased RBE, decreased OER, and reduced repair. We predict that the use of beams of heavy ions in cancer therapy will create late effect problems for fractionated therapy. We highlight also the damage by "ion-kill", from single heavy ions in the cosmic rays, to the central nervous system in space flight.

d. The coupling of Katz theory and the NASA theory of heavy ion diffusion and penetration through matter, and knowledge of the space radiation environment, has been applied to design of shielding, to the cell damage in space flight.

e. As yet we have not contributed to the design of dosimetric systems yielding knowledge of the ion kill and gamma kill damage fractions in space flight. We have suggested that this might be accomplished through use of one and two hit detectors, such as TLD's.

f. As yet we have not calculated the response of cells in vitro to neutrons currently used in cancer therapy, though is contemplated. We wish to examine the implications of ion-kill from heavy fragments in neutron therapy and thus to estimate problems with neutrons in space flight.

g. Our studies of ground based experiments in radiobiology and in cancer therapy are made to substantiate our theoretical model of the biological effects of energetic heavy ions, which, incidentally, is the only predictive model in this discipline. In support of this claim we point out that we have predicted the effects of single protons and single alpha particles incident on cell nuclei, in the latest microbeam experiments. These predictions are made from Katz theory, and the cellular radiosensitivity parameters extracted from experiments at high LET and high dose levels. The theory then predicts response at the lowest possible fluence levels (single electrons and single heavy ions).

All funds available in the present contract have been expended.

PUBLICATIONS, PRESENTATIONS, REPORTS

7/1/92 - 10/31/98

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II. ABSTRACTS AND PROCEEDINGS

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